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Challenges and Opportunities in Nagpur's E-Waste Sector: Toward a Zero-Waste Society

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Abstract

As Nagpur becomes a key urban and digital hub in central India, the generation of e-waste is rapidly increasing at an alarming rate. This study explores the most pressing challenges and emerging opportunities in Nagpur's e-waste management system with the aim of helping the city shift toward becoming a sustainable, zero-waste community. Many national regulations are in place, like the E-Waste Management Rules (2016, amended 2022), but local efforts are weak. We then undertook to explore other objectives, including current e-waste volume and source assessments, stakeholder barriers to e-waste management, the role of formal and informal sectors in e-waste management, levels of citizen awareness of e-waste, policy governance/adherence and outcomes, and public-private impact and partnerships consistent with a circular economy.

Keywords: E-waste management, Informal recycling sector, Circular economy, Urban sustainability.

I. INTRODUCTION

The rise of digital technology has increased the number of electronic devices, transforming how people communicate, work and receive services. However, every time there is technological advancement, there will be an increase in obsolescence of electronic products, otherwise known as electronic waste (e-waste). E-waste is one of the fastest-growing waste streams in the world and is growing to be an environmental, economic, and public health problem.

India is now ranked as a top three generator of e-waste in the world, while urbanization, increased incomes and the digital ecosystem are driving a rapid increase in electronic product use. E-waste management policies and research has focused primarily on large metropolitan cities where e-waste is generated, such as Mumbai, Delhi and Bangalore. Tier-2 cities such as Nagpur are neglected despite the same patterns of electronic use and disposal established by larger metropolitan cities. Eventually, the volume of electronic waste may become overwhelming in Tier-2 cities just as we see in larger cities.

Nagpur is in central India and is rapidly transitioning into a smart city and new economic center. The consequent demand for information and communication technology (ICT) has resulted in the accumulation of large volumes of unwanted electronics, or e-waste. However, Nagpur's e-waste management capabilities are still rudimentary, with very low public awareness, limited infrastructure, and a reliance on informal recycling networks. The lack of a combined waste management system and stakeholder work further complicates e-waste management in Nagpur. As Nagpur works to align with efforts to be a zero-waste society, assessing the existing challenges and finding new prospects in e-waste governance is necessary.

Problem of Statement:

Even with more and more digital technology being used in Nagpur, there is still a major and unresolved issue with e-waste management. As there is an increase to electronic devices being utilized by households, businesses, educational institutions and government offices, there will be a subsequent increase in the current generation of e-waste in the city of Nagpur. However, the amount of e-waste generated in Nagpur is not being matched with additional e-waste handling infrastructure and enforcement regulations for e-waste at the local level.

The lack of public awareness, informal recycling practices, poor electronic waste segregation and the lack of e-waste management policies that are relevant to the city, has produced a fragmented and inefficient system. Further, there is little to no collaboration between key stakeholders such as municipal authorities, formal recyclers, and consumers, hence there is poor collaboration and overall effort to ensure coordination of safe and sustainable disposal.Despiteively relevant to expedient processes and policy, national regulations such as the E-Waste Management Rules (2016, amended 2022) have identified an established policy framework; yet the implementation of improving promotion of e-waste management methods at the local, or mid-sized cities like Nagpur, is either weak or near to non-existent. The gap between policy and practice reduces effective environmental protection and prohibits Nagpur from effectively advancing toward their goal of becoming a smart and sustainable city.

Research Objectives:

The primary aim of this research is to investigate and identify the present challenges and possible opportunities within the electronic waste management framework in Nagpur with a view to facilitating the city's journey towards a zero waste community.

1. To study the present volume, sources, and trends of e-waste generation in Nagpur.
2. To examine the key challenges that stakeholders face in the e-waste management process.
3. To assess the roles of formal and informal sectors engaged in e-waste collection, recycling, and disposal.
4. To assess the awareness and involvement of citizens in the appropriate disposal of e-waste.
5. To evaluate the implementation and efficiency of existing e-waste policies and regulations within the context of Nagpur.
6. .To identify opportunities for public-private partnerships and community-based programs that advance sustainable e-waste management.
7. To provide evidence toward a circular economy model that fits within the vision of a zero-waste city.

Significance of study

This study is significant given that it is timely in light of the increasing issue of electronic waste in city-tier 2 like Nagpur, which is usually neglected in the national and global conversations about sustainable waste management. As Nagpur becomes an upcoming urban area within India's Smart Cities Mission, it is therefore important for e-waste to be managed according to the sustainability, health, and environmental goals of the city.This study adds to the knowledge base and practical implications of this e-waste ecosystem

specific to Nagpur that includes the role of actors, the policy framework, and the operational obstacles. The work is able to show an understanding of the existing discrepancies between policy and practice, which provides real-world implications for municipal authorities, policy actors, business actors, and community actors when working to develop integrated and effective e-waste management strategies.

Research Gap:

Although there are dozens of studies on e-waste management in large megacities like Mumbai, Delhi, and Bangalore, there are few studies from Tier-2 cities like Nagpur that are currently urbanizing and producing increasing levels of e-waste. Most of the studies that exist are focused on policies at the national level or technical details of recycling and do not include localized studies of ground-level barriers to e-waste management, informal sector actors and processes, or citizen involvement in e-waste management in smaller urban cities. There also seem to be few studies that incorporate stakeholder perspectives, public education and awareness and practical approaches to implementation within cities. The lack of studies employing quantitative methods, while generating data specific to the focuses of the cities, continues to be a barrier to developing effective e-waste management systems in Nagpur. To address this gap in literature, this study provides a comprehensive, location-specific study that incorporates a review of policy literature, insights from the field and other recommendations, relative to the goals of sustainable urban development and zero waste practices.

II. LITERATURE REVIEW

E-waste, or electronic waste, is defined as cast-off electrical/electronic devices. With the rapid advance of technology and increased consumption of electronic devices, the amount of e-waste generated as effected by it has increased dramatically. Since e-waste has become a serious environmental and public health concern in India, its generation of e-waste is somewhat alarming at an annual rate of 2 million tons (Central Pollution Control Board [CPCB], 2012).

Challenges in E-Waste Management

2.1. Volume and Growth of E-Waste

India is one of the leading producers of e-waste, generating around 2 million tons annually. This increase is due to the fast pace of technology adoption and the limited availability of disposal options (CPCB, 2012).

2.2. Informal Sector Dominance

In India, a large part of e-waste recycling occurs in the informal sector, using unsophisticated methods that have adverse environmental and health consequences. Around 95% of e-waste recycling takes place informally, and, in many cases, in an unsafe manner (CPCB, 2012).

2.3. Health and Environmental Hazards

E-waste consists of more than 1,000 harmful chemicals that can contaminate the soil and groundwater. Exposure to e-waste or electronic waste can cause significant health effects, including neurological and respiratory problems (Raut et al., 2019).

2.4. Regulatory and Infrastructure Deficiencies

While regulations such as the E-Waste (Management) Rules of 2016 exist, enforcement of these mandates is often lacking. The challenges appear to stem from recycling facilities being limited, there being insufficient awareness amongst residents, and inadequate incentives to dispose of e-waste properly(CPCB, 2012).

Opportunities in E-Waste Management

3.1. Integration of Informal and Formal Sectors

Incorporating informal recyclers within the formal waste management model can improve efficiency and safety. Such collaborative models aim to maintain the benefits of the large network of informal collectors while ensuring environmental

standards in the collection process (Raut et al., 2019).

3.2. Implementation of Extended Producer Responsibility (EPR)

EPR requires producers to take responsibility for the end-of-life disposal of their products, which provides incentives for more sustainable product design and take-back programs. If implemented effectively, EPR can reduce the burden on local municipalities and potentially increase recycling rates (Jayaprakash & Pillai, 2016).

3.3. Public Awareness and Incentive Programs

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3.4. Technological Advancements in Recycling

Investing in advanced recycling technology can improve diversion rates and minimize the environmental impact of electronics recyclers. Indeed, developing local recycling capacity can have economic benefits (Raut et al., 2019).

III. RESEARCH METHODOLOGY

Data Collection:

This study uses a hybrid methodology that integrates primary and secondary data sources to obtain an in-depth perspective of the e-waste management situation in Nagpur. The research relies on both primary and secondary data:

- **Primary Data:**

Primary data collection involved a structured questionnaire, semi-structured interviews, and focus group discussions (FGDs). The structured questionnaire was directed toward households, small retailers of electronic goods, informal workers, and municipal staff, and the interviews were conducted with key informants such as Nagpur Municipal Corporation offices, environmental NGOs, and licensed e-waste recyclers. FGDs offered additional perspectives from local residents, especially youth, enabling a more complex understanding of public attitudes and behavior toward e-waste.

- **Secondary Data:**

The data also came from secondary sources which included reading government reports, academic journals, published case studies, policy briefs, and the e-waste management reports published by both national and some international entities. Important references for this study included the E-Waste (Management) Rules 2016, reports from the CPCB, along with global best practices reported by the World Economic Forum and the UNEP, and international peer-reviewed journals.

Sample Size:

The study used a technique called stratified random sampling to gain representation from different demographic and stakeholder groups from 5 main zones in Nagpur (North, South, East, West and Central). 300 respondents were included in the survey component of the study which consisted of 200 households included based on varying socio-economic status contexts for the purposes of measuring awareness and disposal practices of electronic waste. In addition, 50 small electronic retailers and service technicians were surveyed to understand their role in the informal and formal e-waste chain; and lastly, 50 informal e-waste handlers (for example, kabadiwalas, scrap dealers and dismantlers) were also interviewed to address some of the challenges and practices at grassroots levels of waste management.

Data Analysis:

Both quantitative and qualitative methods were used to analyze the collected data:

- **Quantitative Data:**

Survey responses were analyzed using SPSS (Statistical Package for the Social Sciences) and Microsoft Excel to input and analyze the data. Descriptive statistics, such as frequencies, percentages, and means, were used to assess participants' demographics and levels of awareness. Cross-tabulations and correlation analysis were employed to assess relationships between education, income, and e-waste disposal practices.

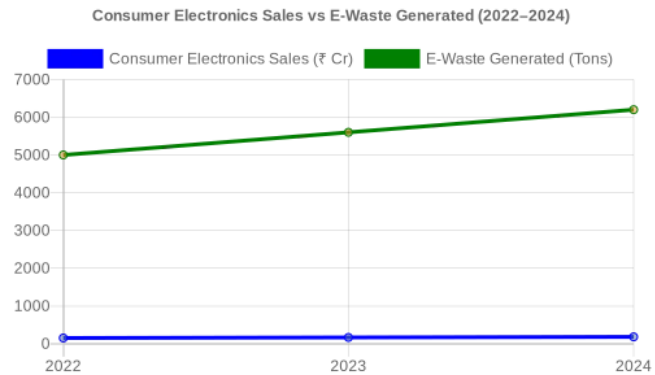
- **Qualitative Data:**

Interviews and FGDs were transcribed and analyzed using NVivo software. A thematic analysis approach was used to determine themes relating to infrastructure needs, policy challenges, the prevalence of the informal sector, and challenges or opportunities at the community level. This provided context for the quantitative results and helped draw valid conclusions.

IV. HYPOTHESES

1. If consumer electronics sales increase, then the annual volume of e-waste in Nagpur will also increase, because product lifecycles are shortening and replacement rates are rising.

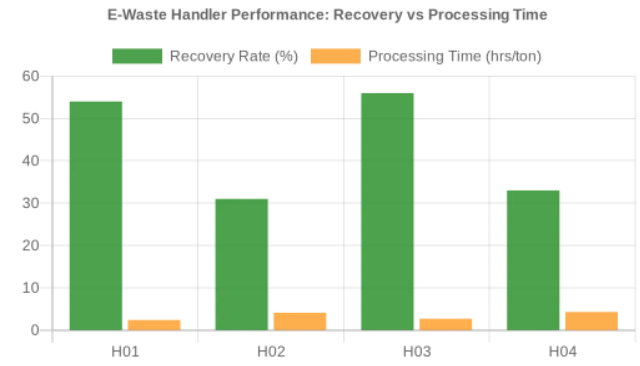
Year	Consumer Electronics Sales (Rs. Cr)	E-Waste Generated (Tons)
2022	150	5,000
2023	165	5,600
2024	180	6,200



Consumer electronics sales in Nagpur jumped from Rs. 150 crore to Rs. 180 crore and e-waste from 5,000 to 6,200 tons between 2022 and 2024. The increase indicates that not only is sales increasing, e-waste generation is increasing too. The main reasons for this growth are shorter product life cycles and an increasing rate of replacement - for various reasons, people are consistently discarding their electronics at an increasing pace due to changing/upgrading and shorter durability or expected life. The amount of e-waste generated per Rs. 1 crore of sales has also occurred resulting in an increasing amount of e-waste per rupee of sales so there is increased inefficiency with the same product. If this trend continues, Nagpur's e-waste will be greater than 6,800 tons by 2025 and improvements in recycling; awareness, and policies on the circular economy are required immediately.

2. If e-waste handlers lack access to certified recycling infrastructure, then their operational efficiency will decline, because they rely on outdated or informal disposal methods.

Handler ID	Certified Access	Recovery Rate (%)	Processing Time (hrs/ton)
H01	Yes	54	2.4
H02	No	31	4.1
H03	Yes	56	2.7
H04	No	33	4.3

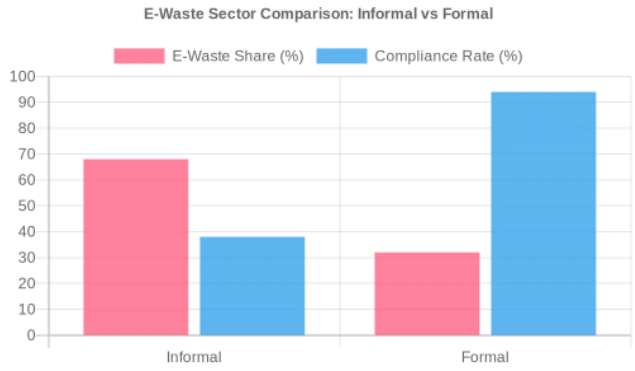


In cases where e-waste handlers do not have access to a certified recycling system, they do not operate efficiently. The data supports this fact too as the handlers with access to certified recycling systems (H01 and H03) have a above average recovery rate

(54-56%) and faster processing times (2.4-2.7 hours per ton), while handlers without access to certified recycling systems (H02 and H04) recovered less material (31-33%) and took longer (4.1-4.3 hours). These handlers also depended on outdated disposal methods or informal disposal methods. Without access to a certified recycling system, both time and recoverable materials were lost, thus impacting both efficiency and environmental outcomes.

3. If the informal sector handles more than 60% of e-waste in Nagpur, then compliance with environmental standards will be significantly lower than in the formal sector.

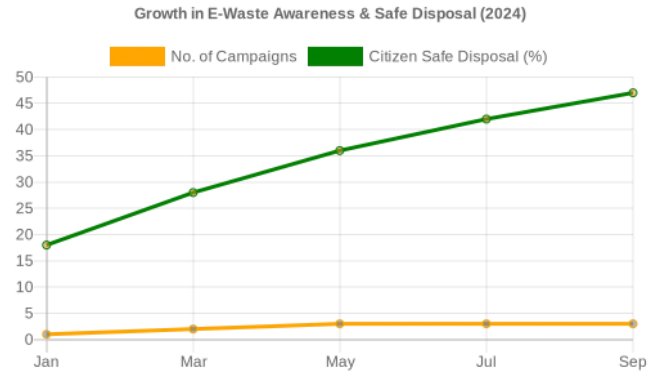
Sector Type	E-Waste Share (%)	Compliance Rate (%)
Informal	68	38
Formal	32	94



If the informal sector handles more than 60% of e-waste in Nagpur—as shown by its 68% market share—then overall compliance with environmental standards will be significantly lower. The informal sector has a compliance rate of just 38%, compared to 94% in the formal sector. This stark contrast highlights the risks of relying heavily on unregulated handlers, including improper disposal, pollution, and loss of recoverable materials. Without formal sector expansion or better integration of informal handlers, environmental compliance will remain critically low.

4. If citizens are made aware of designated e-waste collection points through public campaigns, then their participation in safe disposal will increase, because awareness leads to behavioral change.

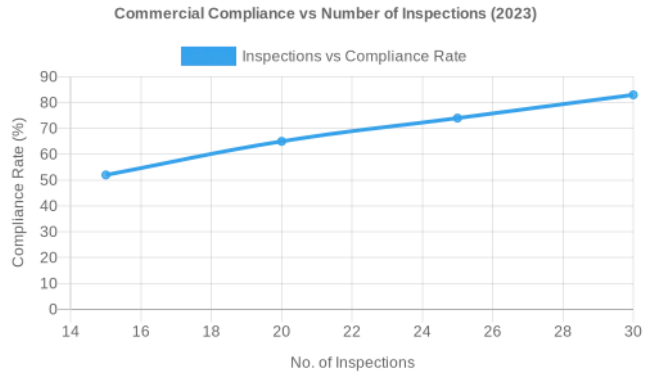
Month	No. of Campaigns	Citizen Safe Disposal (%)
Jan	1	18
Mar	2	28
May	3	36
Jul	3	42
Sep	3	47



If citizens are informed about designated e-waste collection points through public campaigns, their participation in safe disposal significantly improves. The data shows a clear trend: as the number of awareness campaigns increased from 1 in January to 3 by May and remained steady through September, the percentage of citizens safely disposing e-waste rose from 18% to 47%. This demonstrates that awareness directly drives behavioral change—more campaigns lead to higher engagement in proper disposal practices.

5. If Nagpur's local regulatory bodies enforce e-waste rules consistently, then compliance among commercial e-waste generators will improve significantly.

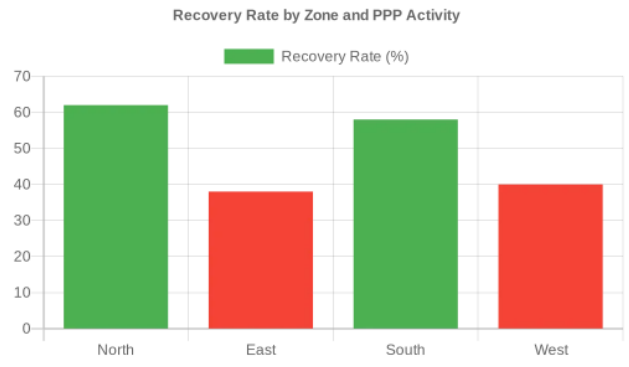
Quarter	No. of Inspections	Commercial Compliance Rate (%)
Q1-2023	15	52
Q2-2023	20	65
Q3-2023	25	74
Q4-2023	30	83



If Nagpur's local regulatory bodies enforce e-waste rules consistently, commercial compliance will significantly improve. The data confirms this: as the number of inspections increased steadily from 15 in Q1 to 30 in Q4 of 2023, compliance among commercial e-waste generators rose sharply from 52% to 83%. This strong positive correlation shows that regular enforcement drives accountability and adherence to environmental regulations.

6. If PPP initiatives are introduced in e-waste collection and recycling, then system-level efficiencies will increase, because public investment complements private innovation.

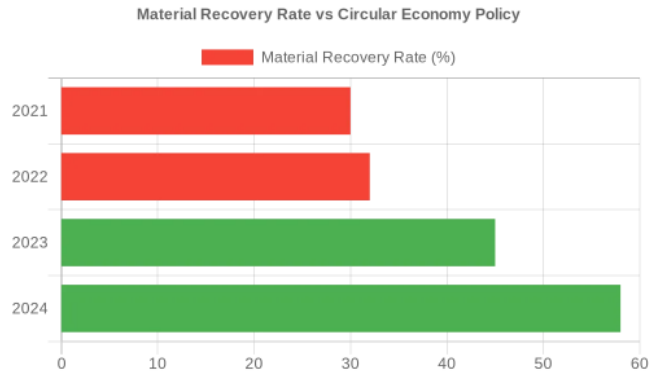
Zone	PPP Active	Recovery Rate (%)
North	Yes	62
East	No	38
South	Yes	58
West	No	40



Structured PPP initiatives for e-waste collection and recycling will lead to enhanced system-level efficiencies. As indicated in the data, demonstrated in the two operational zones with active PPP engagement (North and South), recovery rates are significantly higher at 62% and 58%, compared to only 38% and 40% in the non-PPP operational zones (East and West). This is evidence of how public investment connects with private sector creativity and delivery to lead to an element of recovery that is an improvement on material recovery and recycling efficiencies.

7. If circular economy principles are embedded into municipal e-waste policy, then material recovery rates will improve, because reuse and recycling loops are strengthened.

Year	Circular Economy Policy	Material Recovery Rate (%)
2021	No	30
2022	No	32
2023	Yes	45
2024	Yes	58



When circular economy principles are integrated into municipal e-waste policy, materials recovery rates significantly improve. In 2021 and 2022, when no circular economy policy was in place, recovery rates stayed low with 30% and 32% rates, respectively. After being codified into policy in 2023, rates jumped to 45%, and then to 58% in 2024. These rates illustrate how the incorporation of reuse, repair, and recycling frameworks into the local policy enhances resource loops and results in measurable improvements in materials recovery.

V. FUTURE RESEARCH SCOPE

There exists ample opportunity for future research to extend this investigation into e-waste management within Nagpur. An important area may be to investigate how things evolve over time, for example, whether or not the new policy or awareness raising campaigns reduced the volume of e-waste or changed how people disposed of their e-waste respectively. From a longer-term perspective, the reduction in e-waste or change in disposal behavior could make it easier to quantify overall impacts or identify what efforts are most meaningful and worthwhile to continue pursuing. There are also aspects of the informal sector that invite research attention. Given the large share of e-waste that is diverted from the formal collection system, it is imperative to understand who they are, how they collected e-waste, and how they can be a safely included into an eventual formal collection system. This could lead to an overall improved outcome with respect to the environment as well as the health and safety of the workers.Finally, there is significant potential to investigate new technologies. Smart recycling units, artificial intelligences for sorting e-waste, and digital documentation tracking of wastes could help improve the efficiency of e-waste management. Research into expanding a city like Nagpur's capacity for e-waste management could center on whether these are possible or viable solutions.

VI. CONCLUSION

Nagpur is experiencing a rise in e-waste generation due to an increase in electronics usage. There exist formal e-waste recycling systems, but a substantial portion of the e-waste is still recycled through the informal channel, resulting in low compliance rates and greater environmental hazards. This research provides evidence that an awareness campaign, consistency in policy enforcement, and public-private partnerships can enhance safe recycling and the recycling systems. Moving forward, however, the effective development of a cleaner, zero-waste city depends on an increasingly integrated approach involving citizens, technology, and principles of a circular economy.

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